# Identification and Evaluation of Viable Remediation Alternatives to address Injuries related to Land Disposal of Poultry Waste within the Illinois River Watershed

Prepared by: 5/15/2008

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My fee for this work is $175 per hour in accordance with the contract terms and conditions between Motley-Rice and CDM.

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(4) compare to other technologies identified to determine relative benefits.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

### 3.2.1.2 Treatment

*Buffer strips adjacent to streams and rivers* – Also known as vegetative filter strips (VFS), grass or other plants are strategically placed in areas to catch nutrient runoff or capture nutrients through infiltration. Placing buffer strips along the fields is an option that is commercially available, implementable and potentially effective (Edwards et al., 1994).
RETAINED FOR REMEDIAL EVALUATION.

*Chemical treatment of fields and pastures with alum (alum field application)* – Aluminum sulfate (alum) has been reported to reduce the amount of soluble P when used as a chemical treatment to poultry waste prior to spreading on fields (Moore et al., 2007). Alum is commercially available and the technology is implementable. However, the effectiveness of alum in immobilizing P in-situ to fields and pastures as found within the IRW has not been demonstrated on a large-scale basis. For this reason, this technology requires additional investigation and assessment.

Potentially, alum would be applied to land where poultry waste has been applied, and excess P persists. The long-term effectiveness of alum amended poultry waste was tracked as it was applied to several fields over seven years (Moore and Edwards, 2007) where reductions of soluble P were up to 87%. However, aluminum can potentially damage aquatic ecosystems and is potentially phytotoxic to plants at low pH. Moore and Edwards (2005) found the amounts of aluminum in runoff were similar from fields with plots applied with treated and untreated poultry waste. Additional studies would focus on quantifying the reduction in P runoff and leaching from fields and potential impacts to pH to determine if aluminum toxicity is of concern. CDM identified no long-term studies of alum applied directly to poultry waste impacted land to reduce P runoff and leaching.

Additional studies would address the effectiveness of alum application as it relates to the reduction in P loading to the watershed based on the following factors: application method, location, environmental impact, reduction in runoff P, reduction in leaching P, pH changes and potential toxicity of aluminum.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

*Chemical treatment of fields and pastures with lime* – Treating fields with lime is commercially available and implementable. With respect to the treatment of poultry waste prior to field application, Moore and Miller (1994) tested four forms of lime and alum and found treatment of poultry waste with alum, calcium oxide (CaO) and calcium hydroxide ($Ca(OH)_2$) effective at reducing P in runoff from fields fertilized with poultry waste. However, calcitic and dolomitic limestone was ineffective in reducing P in runoff. Alum has been found to be more effective than lime in reducing P runoff in poultry waste studies. Further, CDM identified no long-term

viable hydrologically; (2) likely reductions in P; and (3) cost effectiveness.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

*P inactivation with alum*—Aluminum sulfate (alum) is commonly used as a treatment to reduce P from continuously cycling in a lake (Cooke at al., 2005). However, it has not been as widely used in river systems. Potential negatives associated with riverine alum application include the production of particulate floc that may cause siltation of aquatic habitats and fish gills and potential aquatic toxicity due to aluminum. Further, the P removal is short term and repeated applications would be required to provide P removal on an ongoing basis. Therefore this technology has not been retained.
NOT RETAINED.

*P inactivation with ferric or lime*—Ferric or lime treatment is used to remove P from wastewater and is commercially available. However, the potential negatives associated with ferric or lime application includes harm to aquatic habitats and fish gills from siltation. Further P removal is short term and repeated applications would be required to provide P removal on an ongoing basis. Therefore this technology has not been retained.
NOT RETAINED.

*Drinking water surface water treatment*— Surface water treatment is commercially available and implementable, but is only effective on the drinking water. It does not address other injuries. This technology consists of the removal of algae and other disinfection byproducts such as THM and HAA5 precursors that would result in unacceptable risks to human health after chlorination and disinfection of drinking water. This technology is retained for remediation to reduce risks to human health.
RETAINED FOR REMEDIAL EVALUATION.

*Re-impound Lake Francis*—Lake Francis is a former impoundment near Siloam Springs and the border of Arkansas and Oklahoma. The dam that formed Lake Francis was breached during a flood in 1992. Re-impounding this area could capture sediments and reduce P loading to Lake Tenkiller. An investigation by the U.S. Geological Survey (USGS) found that approximately 26 percent of the total P load into former Lake Francis was retained between 1998 and 2000. However soluble reactive P retention for the same period was negligible (Haggard, et al. unpublished). USGS postulated that sediment that total P removed was due to sediment deposition and may be resuspended during massive flooding. The re-impoundment of Lake Francis would need to evaluate the potential benefits to IRW in terms of P removal against the potential ecological impacts of re-flooding the impoundments along with the resulting loss of habitat and wetlands. If this technology was implemented, existing sediment and future sediment deposition would need to be removed to prevent the solubilization of P from sediment during anaerobic conditions (Haggard and Soerens, 2006). Based on the ineffective removal of soluble P and the negative ecological impacts of re-impounding Lake Francis, this technology has been eliminated.
NOT RETAINED.

remediation to reduce risks to human health.
RETAINED FOR REMEDIAL EVALUATION.

*Reservoir management, lake water drawdown*—Drawdown is commercially available and implementable, but would not be effective. Generally, this technology is not effective for P removal from a reservoir.
NOT RETAINED.

*P inactivation with alum*—Aluminum sulfate (alum) is commonly used in lakes as a treatment to reduce the flux of P from sediments (Cooke et al., 2005). This treatment is commercially available, implementable, and potentially effective. However, in a reservoir, such as Lake Tenkiller, high dosages and repeated applications may be needed to be potentially effective in sequestering sediment P. With higher dosages, there is the potential for localized depression of pH with an associated potential increase in aluminum toxicity to aquatic life.

Alum treatment of Lake Tenkiller could potentially reduce the internal loading of P from lake sediments. Using alum typically increases the water clarity. Alum can be toxic to aquatic life at low pH (Cooke et al., 2005). Alum applications are generally effective in lakes from 5 to 15 years (Welch and Cooke, 1999). However, the duration of alum treatment effectiveness in a reservoir such as Lake Tenkiller will not be as long as a lake and will be further reduced proportional to the additional P inputs from the Illinois River, Caney Creek and the Baron Fork. Therefore, the applicability of P inactivation with alum cannot be adequately evaluated until the final remedial measures for the watershed and riverine response regions have been identified in sufficient detail to determine future P and nutrient loadings to Lake Tenkiller.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

*P inactivation with ferric or lime*—Ferric or lime treatment is commercially available and implementable, but its effectiveness on P inactivation relative to alum is lower and costs for application and raw materials are generally much greater than alum.
NOT RETAINED.

*Hypolimnetic withdrawal*— Hypolimnetic withdrawal is a lake restoration technique in which siphons or other structures are used to remove nutrient rich water from the bottom portion of the lake (hypolimnion). Nutrient concentrations are reduced utilizing this method when P concentrations are higher in the hypolimnion as compared to the overlying water layers. The technology is commercially available, implementable, and effective. This is currently the mode of operation for Lake Tenkiller dam. No evaluation of alternative draw offs is warranted.
NOT RETAINED, ALREADY IMPLEMENTED

*Artificial circulation*— Artificial circulation provides mixing to lakes utilizing mechanical mixing or aeration systems. This technology is usually used for shallow water bodies. It is commercially available, but difficult to implement on a large deep

# Section 4
# Detailed Evaluation of Remedial Alternatives

## 4.1 Overview

This section develops and evaluates alternatives for remedial options in more detail. Each technology can then be compared to assess performance relative to the evaluation criteria. The following identified preliminary remedial technologies were evaluated based on response region and media that the technologies will be applied:

I) Watershed Response Region
 1) Removal – Cessation of land application within the IRW and proper poultry waste management
 2) Treatment – Buffer strips/vegetative filter strips
 3) Treatment – Residential treatment system for drinking water
 4) Treatment – Residential supplied drinking water
 5) Treatment – Residential replacement of groundwater wells

II) Riverine Response Region
 1) Treatment – Drinking water surface water treatment

III) Lake Tenkiller Response Region
 1) Treatment – Drinking water surface water treatment

## 4.2 Evaluation Criteria

Remedial technologies are discussed in detail according to the following criteria:

- *Overall protection of human health and the environment* – Benefits to human health and the environment are considered, including an alternative's protectiveness and reduction potential for exposure and risk.

- *Compliance with potentially applicable legal requirements* — Alternatives must also consider state and federal laws during the process of remediation. These laws can be chemical specific, action specific or location specific. Chemical-specific laws include federal and state regulations of specific contaminant levels (e.g. phosphorus, bacteria). Action-specific laws regulate the technologies or activities used for the remediation technology. For example, laws for dredging would include all regulatory requirements for dredging and disposal. Location specific laws are relevant regulations specific to a geographic location. For example, actions on wetlands or critical habitats would require compliance with federal and state regulations for wetlands. The list of laws considered is included as Table 4-1.

- *Long-term effectiveness and permanence*—This criterion evaluates the effectiveness of an alternative over time, after implementation.

- *Reduction of toxicity, mobility, or volume through treatment*—This criterion evaluates the ability of a technology to reduce the toxicity, mobility, or volume of the contaminant of concern through treatment.

- *Short-term effectiveness*—This criterion considers the effectiveness during construction or implementation of the alternative.

- *Implementability*—The commercial availability and the ability to execute and complete an alternative are considered in this criterion.

- *Cost*—This criterion considers the overall costs of the technology. This includes short term capital and operating costs, operation and maintenance, and other direct and indirect costs.

## 4.3 Watershed Response Region

Retained technologies for the watershed response region address the transport of P to rivers and streams and residential drinking water impacted by bacteria and nitrogen. Excess P exists in the soils where poultry waste has been applied. Remediation technologies attempt to address human health and the removal of excess P and other nutrients to stop their continual input into IRW rivers and streams and Lake Tenkiller.

### 4.3.1 Removal - Cessation of land application within the IRW and proper poultry waste management

Grasslands, pastures and fields that have been used repeatedly for the application of poultry waste for fertilization and disposal have received loadings of P that far exceed the agronomic requirements of grass, hay and other crops grown on them. These areas of land have resulted in the runoff and leaching of P which has resulted in the injuries listed in Section 2.1. The ability and effectiveness of all of the remedial options to reduce N, P and bacterial loadings will be impaired without the cessation of land application of poultry waste within the IRW. Without cessation, the loading of P to the rivers, streams and Lake Tenkiller will likely increase over the next 30 years based on the IRW watershed-wide model (B. Engel, 2008).

*Overall protection of human health and the environment* – The elimination of poultry waste land application within the IRW will reduce the loadings of P, N and bacteria to the river and streams of the IRW and Lake Tenkiller. Bacteria will die off over time naturally. Generally, N is not the limiting nutrient in the IRW system and therefore the reduction in N will not result in significant improvements to human health and the environment. P will gradually leach from the soil over time. Initial predictions indicate that P loadings will decline approximately 17 percent during the first decade of cessation and are expected to attain a 50 percent reduction after 50 years (B. Engel, 2008).

*Compliance with potentially applicable legal requirements* – This technology can be implemented in compliance with all potentially applicable legal requirements.

*Long-term effectiveness and permanence* – This technology would be effective in reducing N, P and bacteria. However, the existing inventory of P will likely leach at elevated levels for the next 100 years with cessation alone.

*Reduction of toxicity, mobility, or volume through treatment* – This technology would reduce toxicity, mobility and volume of bacteria through natural die off. N and P will continue to leach from the soil column into groundwater and surface waters.

*Short-term effectiveness* – Cessation and proper poultry waste management within the IRW will have no short term negative impacts on the IRW.

*Implementability*—This technology is implementable.

*Costs*—Costs of this technology are dependent on the methods chosen by the Defendants to manage poultry waste in accordance with applicable laws and regulations. As a point of reference, disposal of poultry waste within a licensed landfill was estimated by the Defendants at approximately $35 per ton. This results in the following costs: capital costs -- none; annual costs were estimated to be $16 million; and total present worth cost over 30 years was estimated at $200 million.

### 4.3.2 Treatment - Buffer strips/vegetative filter strips

Various terms have been used to define vegetation planted to prevent nutrient inflow, including buffers, riparian strips, and filter strips. For the purposes of this report, the term vegetative filter strips (VFS) will be used. VFS are areas of plants used to prevent the infiltration of sediments or nutrients into receiving waters (Fischer and Fischenich, 2000). Trees, herbs and grasses can be used in various densities to create a VFS.

VFS removes P by: (1) slowing overland flow and allowing P-laden sediment to settle and be retained within the VFS; and (2) growth of biomass within the VFS uptakes P from the settled sediment and soil. The major mechanism for VFS to be effective is to change flow hydraulics and slow down surface water. As surface water passes slowly and uniformly, sediment is deposited and suspended sediment is filtered by vegetation. Soluble particles are usually removed by infiltration and sorption by the soil/plant matrix.

VFS design is important in targeting the success of specific contaminant removal. Design elements include 1) width 2) slope and 3) type of plantings used.

*Overall protection of human health and the environment* – Removal of P through the use of VFS is partially protective of human health and the environment based on the reduction of P loading to rivers, streams and Lake Tenkiller and the associated reduction in P related injuries. Other benefits of creating VFS include stabilizing field or river bank areas and increasing accessibility for wildlife (Fischer and Fischenich, 2000).

*Compliance with potentially applicable legal requirements* – This technology can be implemented in compliance with all potentially applicable legal requirements. Soil erosion permits and controls would be required for disturbed areas that exceed the regulatory threshold. For those areas affecting wetlands, the following citations are relevant:

- Rivers and Harbors Act of 1899 (33 USC 403). If wetlands are to be created or the course of the river modified in any way, permits would need to be applied for through the Army Corps of Engineers.

- Executive Orders 11990-Protection of Wetlands and 11988-Floodplain management (40 CFR 6.302 40 CFR 6, Appendix A; OSWER 9280.0-03). This law is relevant if federal agencies are involved in the creation of the buffer zones which modify wetlands or floodplains.

*Long-term effectiveness and permanence* – Design of VFS is important in its success of preventing nutrients from entering a water body. VFS width, slope, and type of plant material all factor into its long-term effectiveness. Filters are able to reduce sediment and suspended solids from runoff as long as surface flow is shallow and uniform (Dilaha, 1989). Maintenance of VFS needs to be considered as well (Grismer et al., 2006).

Effectiveness can range from 50-98% for sediments and decreases with increased sedimentation over the years. VFS are not always effective at removing soluble P and N (Dilaha, 1989), however. Based on these considerations, cessation of poultry waste land application is required for VFS to be effective over the long term. The continued application of poultry waste would result in the build up of P within the VFS and eventually reduce the P removal efficiency such that there could potentially be no net removal of P loading from rivers and streams as compared to current conditions.

The reduction in P loadings to the streams and rivers of the IRW and Lake Tenkiller were estimated using two scenarios, placement of VFS with a width of 100 feet on both sides of streams and rivers that intersect pastures or grassland for: (1) all streams within IRW (estimated at 84,927 acres); and (2) for streams 3$^{rd}$ order and above (estimated at 13,347 acres). Resultant P reductions were estimated using a model with a simulation period of 100 years. Under the all stream scenario with cessation of poultry waste land application at year 0, average P reductions ranged from a high of 13.6 percent (decade 2) to a low of 10.6 percent (decade 10). Under the 3$^{rd}$ order and above stream scenario with cessation of poultry waste land application at year 0, average P reductions ranged from a high of 5.4 percent (decade 1) to a low of 3.3 percent (decades 9 and 10).

*Reduction of toxicity, mobility, or volume through treatment* – Different types of VFS effect the reduction of P and N (Fischer and Fischenich, 2000). Chaubey et al. (1995) found a 89% reduction of soluble P, 91% reduction for total P and a reduction ranging from

19-26% total suspended solids for filter strips of fescue 21.0 m wide. Two model scenarios were developed and run to determine the overall effectiveness of VFS for 3rd order and above streams and for all streams. VFS were modeled based on land use maps and stream data in a geographical information system (GIS) framework. Where fields intersected streams or rivers, a 100 feet wide VFS was assumed. It should be noted that the "all streams" scenario does not include the large number of ditches and swales that drain fields, grasslands and pastures within the IRW and therefore total P removals estimated with respect to long-term effectiveness and permanence do not approach the literature reported removal efficiencies.

*Short-term effectiveness* – Constructing VFS would create the potential for increased erosion and P loading to river and streams. Work practices and soil erosion control would mitigate this potential and minimize short-term releases of P.

*Implementability*—Information on design standards and target nutrients is readily available (Fischer and Fischenich, 2000; Grismer et al., 2006; Mayer et al., 2005; and Parkyn, 2004). Regional studies specific to the IRW area and the poultry industry are also available. Chaubey et al., 2005 studied effectiveness of filter strips in poultry areas in Arkansas. Edwards et al. (1996) developed a readily applicable VFS design procedure using a hypothetical northwest Arkansas field.

*Costs*— Costs of VFS will vary with types of vegetation used, reduction of land production, and costs associated with planting, establishing and maintaining buffers (Helmers et al., 2006). Costs were developed under two scenarios, VFS placement for all streams within IRW (estimated at 84,927 acres) and for streams 3rd order and above (estimated at 13,347 acres). VFS efficiency and costs were estimated assuming 100 feet widths on both sides of streams or rivers where the land use was pasture or grasslands. The capital costs were estimated at $271 million and $43 million for all streams and 3rd order-plus streams, respectively. Annual costs were estimated at $55 million and $9 million and the total present worth cost over 30 years were estimated at $956 million and $150 million for all streams and 3rd order-plus streams, respectively.

### 4.3.3 Treatment – Residential drinking water

This technology addresses the human health risks present due to nitrogen and bacteria present in groundwater for the impacted drinking water wells of the Oklahoma portion of the IRW. CDM sampled 60 residential domestic drinking water wells in 2006 and 2007. Thirteen percent of the wells tested were reported with total N concentrations exceeding 10 mg/l, indicating a potential exceedance of the nitrate maximum contaminant level for drinking water. Sixty percent of the wells were reported to have a detection of bacteria and 67 percent of the wells were reported to have either N or bacteria exceedances. Extrapolating these findings to the Oklahoma portion of the IRW, an estimated 190 to 980 wells are potentially impacted due to N or bacteria. Cessation is expected to address bacteria through natural die-off (Gerba, et al. 1975). Excess P is not a human drinking water consumption risk in groundwater and is not addressed by this technology.

#### 4.3.3.1 Residential drinking water treatment system

Technologies such as reverse osmosis, ion exchange and ultraviolet treatment can be used as groundwater point of use treatments to remediate high nitrogen and bacteria levels.

*Overall protection of human health and the environment* – Treating drinking water for nitrogen and bacteria on a per residence basis will reduce human health risks associated with contaminated drinking water. No reduction in risk to human health or the environment from P impacts is achieved.

*Compliance with potentially applicable legal requirements* – This technology can be implemented in compliance with all potentially applicable legal requirements. Additional applicable requirements may include:

- Title 785. Oklahoma Water Resources Board
  - Chapter 30. Taking and use of groundwater
  - Chapter 35. Well driller and pump installer licensing
  - Chapter 45. Oklahoma's water quality standards

*Long-term effectiveness and permanence* – With proper maintenance, the treatment system will be effective and permanent.

*Reduction of toxicity, mobility, or volume through treatment* – This technology removes N through ion exchange or reverse osmosis. Bacteria are destroyed through ultraviolet radiation.

*Short-term effectiveness* – This remediation would be immediately effective and initiating it would not be a detriment to human health or the environment.

*Implementability* – These technologies are commercially available and are implementable.

*Costs* – Costs of this technology will vary with the number of wells impacted and types of treatment and capacity. The capital costs were estimated at $0.43 to $4.8 million for N only and N plus bacteria impacts, respectively. Annual costs were estimated at $0.15 to $0.48 million and the total present worth cost over 30 years were estimated at $2.3 to $10.7 million for N only and N plus bacteria, respectively.

#### 4.3.3.2 Residential drinking water supplied

As an alternative to treating groundwater, bottled water can be supplied to eliminate the risk to humans from high nitrogen and bacteria levels.

*Overall protection of human health and the environment* – Providing bottled drinking water for nitrogen and bacteria on a per residence basis will reduce human health risks associated with the ingestion of contaminated drinking water. No reduction in risk to human health or the environment from P impacts is achieved.

*Compliance with potentially applicable legal requirements* – This technology can be implemented in compliance with all potentially applicable legal requirements.

*Long-term effectiveness and permanence* – Because contaminated water is still available in the home, the effectiveness of the system is diminished somewhat.

*Reduction of toxicity, mobility, or volume through treatment* – This technology does not reduce toxicity, mobility or volume through treatment.

*Short-term effectiveness* – This remediation would be immediately effective and initiating it would not be a detriment to human health or the environment.

*Implementability* – This technology is commercially available and is implementable.

*Costs* — Costs of this technology are estimated as follows: capital costs – none; annual costs for N only (190 households) and N plus bacteria (980 households) at 10 gallons per day were estimated at $1.4 and $7.5 million and the total present worth cost over 30 years was estimated at $18 to 92 million, respectively.

#### 4.3.3.3 Replacement of contaminated drinking water wells

Another alternative to address contaminated drinking water wells involves replacement of the existing wells with deeper wells.

*Overall protection of human health and the environment* – Replacement of drinking water wells within the IRW would improve conditions for human health for those with contaminated wells. No reduction in risk to human health or the environment from P impacts is achieved.

*Compliance with potentially applicable legal requirements* – This technology can be implemented in compliance with all potentially applicable legal requirements. Additional applicable requirements may include:

- Title 785. Oklahoma Water Resources Board
  - Chapter 30. Taking and use of groundwater
  - Chapter 35. Well driller and pump installer licensing
  - Chapter 45. Oklahoma's water quality standards

*Long-term effectiveness and permanence* – This technology would be effective provided contamination of N and bacteria have not extended to deeper extents of the aquifer. Cessation of land application of poultry waste is essential to assure that new wells do not become compromised.

*Reduction of toxicity, mobility, or volume through treatment* – This technology would not reduce toxicity, mobility or volume of N, P or bacteria.

*Short-term effectiveness* – Replacement would be effective in the short-term. No human health risks are associated with well replacement.

*Implementability*—The implementability of this technology is limited to those areas where a deeper, uncontaminated aquifer zone is available.

*Costs*—Costs of this technology are estimated as follows: capital costs for 190 new wells (N only) and 980 new wells (N plus bacteria) were estimated at $5.8 and 30 million, respectively; annual costs were estimated to be similar to existing wells and set to zero, which resulted in the total present worth cost over 30 years to be estimated at $5.8 and 30 million, respectively.

## 4.4 Riverine Response Region

Due to the nature of the rivers within IRW, namely coarse sediments with little fines, remedial technologies that might address P removal were screened out based on limited ability to achieve remedial goals. However, drinking water treatment of public water supplies drawing from IRW rivers was retained based on its effectiveness in addressing human health risks related to disinfection byproducts.

### 4.4.1 Treatment – Drinking water surface water treatment

Organic matter is correlated with precursors that form DBPs when drinking water is disinfected. The formation of disinfection byproducts such as THMs and HAA5s can be reduced by using enhanced coagulation, softening or granular activated carbon (GAC) to remove these precursors. This is usually used in systems using conventional filtration treatment (US EPA Office of Water, 2001).

*Overall protection of human health and the environment* – Treating water supplies contaminated with DBPs would reduce the risk of human ingestion. These disinfection by-products are considered probable human carcinogens by US EPA.

*Compliance with potentially applicable legal requirements* –

- Safe Drinking Water Act (40 CFR part 143). Public water systems are regulated under federal standards of SDWA. Remediation would need to be in compliance with these standards.

- The Stage 2 DBP rule (40 CFR, parts 9, 141 and 142). Remediation would put drinking water systems in compliance with this rule, which specifically addresses DBPs.

*Long-term effectiveness and permanence* – Treatment for DBPs with proper operation and maintenance are effective in the long term and permanent.

*Reduction of toxicity, mobility, or volume through treatment* – Treating drinking water supplies for DBPs would reduce the risks of these probable human carcinogens from being ingested. However it does not address the excess P in the IRW that is causing the eutrophication.

*Short-term effectiveness* – The initial implementation of this remediation would not have a detrimental effect on human health or the environment.

*Implementability* — Technologies to reduce DBPs are implementable and readily available.

*Costs* — Costs of this technology were estimated based on US EPA published estimates provided as part of the Federal Register when the disinfection byproduct rule was promulgated (FR Vol 71, No. 2, January 4, 2006 p. 456). Costs were escalated from 2003 dollars to 2008 dollars using the Engineering News-Record Construction Cost Index History. Four water treatment plants (WTPs) used the Illinois River for source water while one WTP used Baron Fork Creek. Capital costs for all five WTPs were estimated at a total of $220 million; annual costs were estimated to be $19 million in aggregate; and the total present worth cost over 30 years for this technology was estimated at $452 million.

## 4.5 Lake Tenkiller Response Region

Several remedial technologies were preliminarily retained from the screening process for the Lake Tenkiller response region. However, additional investigation and assessment will be required to determine their effectiveness and potential value in meeting remedial goals. Therefore, drinking water treatment of public water supplies drawing from Lake Tenkiller was retained based on its effectiveness in addressing human health risks related to disinfection byproducts.

### 4.5.1 Treatment - Drinking water surface water treatment

Organic matter is correlated with precursors that form DBPs when drinking water is disinfected. The formation of DBPs can be reduced by using enhanced coagulation, softening or granular activated carbon (GAC) to remove these precursors. This is usually used in systems using conventional filtration treatment (US EPA Office of Water, 2001).

*Overall protection of human health and the environment* – Treating water supplies contaminated with DBPs would reduce the risk of human ingestion. These disinfection by-products are considered probable human carcinogens by US EPA.

*Compliance with potentially applicable legal requirements* —

- Safe Drinking Water Act (40 CFR part 143). Public water systems are regulated under federal standards of SDWA. Remediation would need to be in compliance with these standards.

- The Stage 2 DBP rule (40 CFR, parts 9, 141 and 142). Remediation would put drinking water systems in compliance with this rule, which specifically addresses DBPs.

*Long-term effectiveness and permanence* – Treatment for DBPs with proper operation and maintenance are long term effective and permanent.

*Reduction of toxicity, mobility, or volume through treatment* – Treating drinking water supplies for DBPs would reduce the risks of these probable human carcinogens from being ingested. However it does not address the excess P in the IRW that is causing the eutrophication.

*Short-term effectiveness* – The initial implementation of this remediation would not have a detrimental effect on human health or the environment.

*Implementability*—Technologies to reduce DBPs are implementable and readily available.

*Costs* —Costs of this technology were estimated based on US EPA published estimates provided as part of the Federal Register when the disinfection byproduct rule was promulgated (FR Vol 71, No. 2, January 4, 2006 p. 456). Costs were escalated from 2003 dollars to 2008 dollars using the Engineering News-Record Construction Cost Index History. Fourteen water treatment plants (WTPs) use Lake Tenkiller for source water. Capital costs for all fourteen WTPs were estimated at a total of $233 million; annual costs were estimated to be $28 million in aggregate; and the total present worth cost over 30 years for this technology was estimated at $583 million.